Inflation Dynamics During the Financial Crisis

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Inflation Dynamics in a Post-Crisis Globalized Economy

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MOTIVATION

- In spite of massive contraction in economic activity during the 2007–09 financial crisis, the general level of prices has remained surprisingly stable.
  Today: Similarly surprising situation in European crisis countries.
- What accounts for the absence of deflationary pressures in light of the enormous and persistent resource slack in the economy?
- This paper investigates the effect of financial conditions on firms' price-setting behavior during the "Great Recession."

OVERVIEW

- Merge item-level prices of individual producers included in the Bureau of Labor Statistics' Producer Price Index (PPI) to their income and balance sheet data from Compustat.
- Analyze how balance sheet conditions influence firm-level price-setting behavior:
  - Investment into customer base $\Rightarrow$ price cut (Rotemberg & Woodford [1991]; Chevalier & Scharfstein [1996])
- Build a DSGE model that embeds financial frictions in a customer-markets framework:
  - Explore output and inflation dynamics in response to demand, supply and financial shocks.
  - What happens at the ZLB?

Data Sources

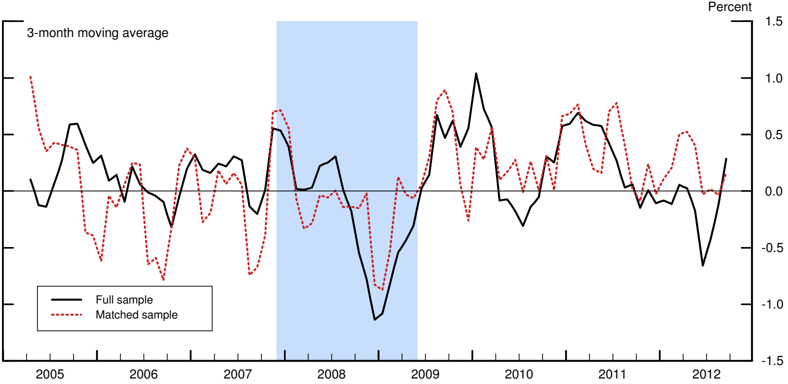
- Monthly good-level price data underlying the PPI. (Nakamura & Steinsson [2008]; Goldberg & Hellerstein [2009]; Bhattarai & Schoenle [2010])
- Match 700+ PPI respondents to their income and balance sheet data from Compustat.
- Sample period: Jan2005–Sep2012

MEASUREMENT

- $i \in I$ items; $j \in J$ firms; $k \in K$ industries.
  - $\tilde{p}_{ijkt}$ = recorded price
  - p^b_{ijkt} = base price (controls for changes in item quality)
  - $p_{ijkt} \equiv \tilde{p}_{ijkt}/p^b_{ijkt}$ = actual (quality-adjusted) price
- Item-level inflation: $\pi_{ijkt} \equiv \Delta \log p_{ijkt}$
- Aggregation:
  - Firm-level inflation: $\pi_{jkt} = \sum_{i \in j} w^I_{it} \pi_{ijkt}$
  - Industry-level inflation: $\pi_{kt} = \sum_{j \in k} w^F_{jt} \sum_{i \in j} w^I_{it} \pi_{ijkt}$
  - Aggregate inflation: $\pi_t = \sum_{j \in J} w^F_{jt} \sum_{i \in j} w^I_{it} \pi_{ijkt}$

Producer Price Inflation Rates

All PPI respondents vs. publicly-traded firms



NOTE: Seasonally-adjusted weighted average inflation at a monthly rate.

Relative Inflation by Firm Characteristics

- Relative item-level inflation: $\hat{\pi}_{ijkt} = \pi_{ijkt} - \pi_{kt}$
- Sorting procedure:
  - In period t, sort firms into categories based on observable characteristics in periods $t-1, t-2, \ldots$.
  - Compute aggregate relative inflation rate in period t for the different categories of firms.
- Financial characteristics:
  - Liquidity: (Cash[t] + LiquidAssets[t])/TotalAssets[t]
  - Cashflow: OperatingIncome[t]/TotalAssets[t-1]
  - Interest coverage: InterestExpense[t]/Sales[t]
- Other characteristics:
  - Customer markets vs. operating efficiency: SGAX[t]/Sales[t]
  - Durability of output: durable vs. nondurable goods

Relative Inflation

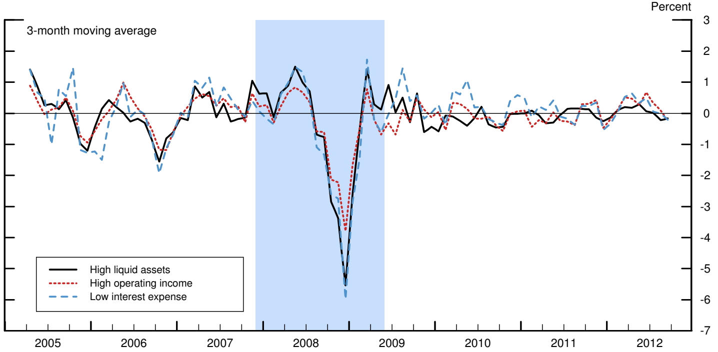
Overview of Results

Main findings:

- 10% difference in monthly inflation between financially constraint and unconstraint firms, relative to industry
  - Large immediate impact
  - Long-lasting, persistent effects
- 6% difference between high and low SG&A firms
- Results driven by non-durable sector

Relative Inflation

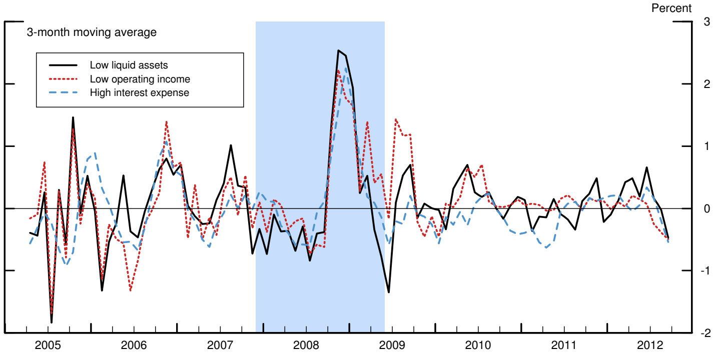
Financially unconstrained firms



NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

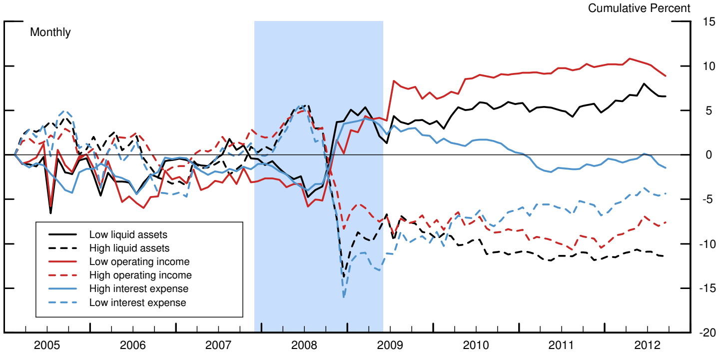
Financially constrained firms



NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

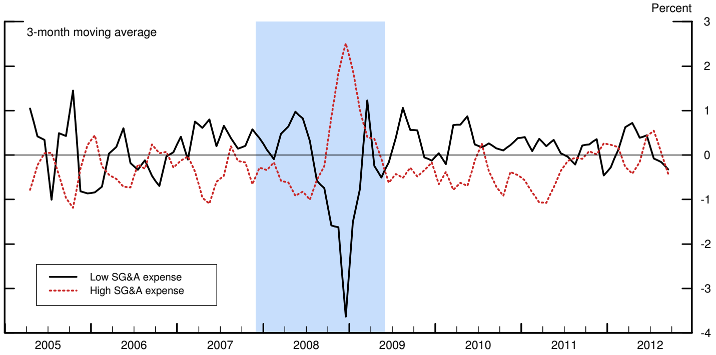
Effect of Financial Frictions, Cumulated Response



NOTE: Cumulated weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

By SG&A expense



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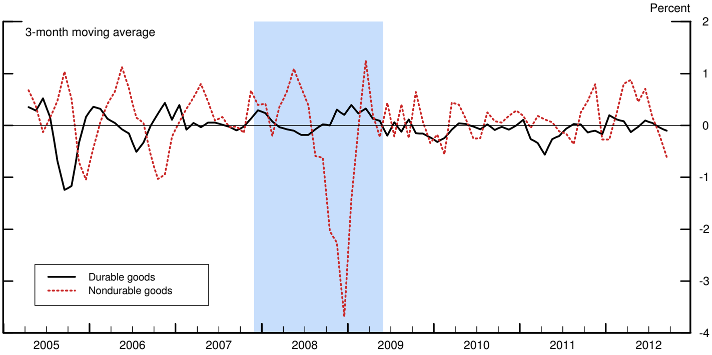
Relative Inflation

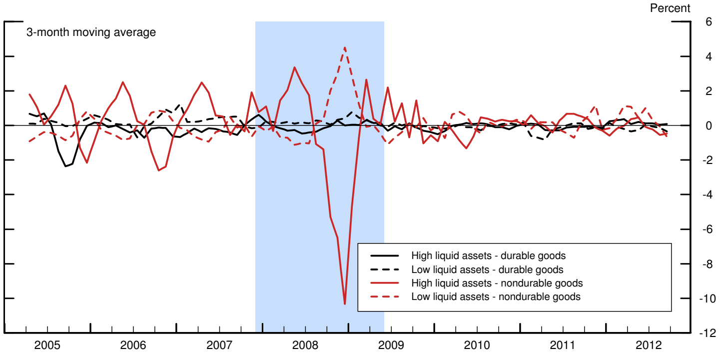
By durability of output



NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

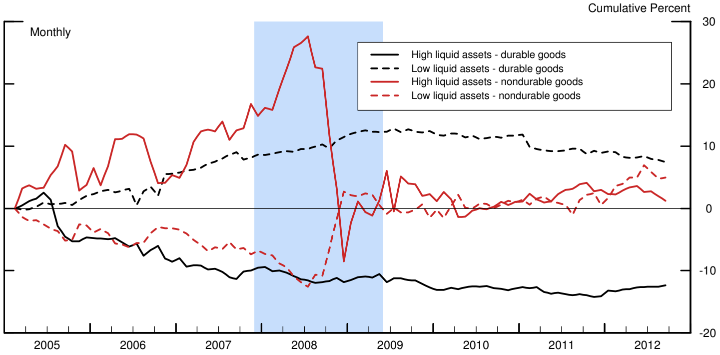
By durability of output and financial condition



NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

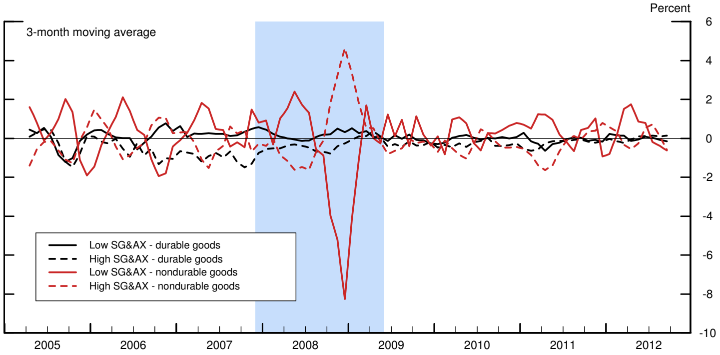
By durability of output and financial condition, cumulated response



Note: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

Relative Inflation

By durability of output and SG&A expense



NOTE: Weighted average monthly inflation relative to industry (2-digit NAICS) inflation.

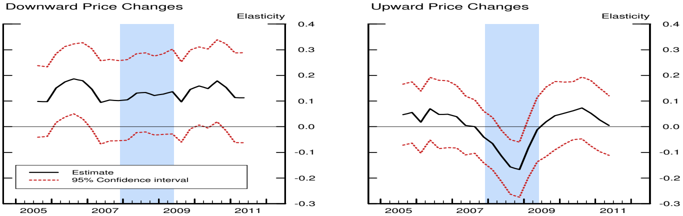
PRICE ADJUSTMENT AND FIRM CHARACTERISTICS

- Multinomial logit specification:

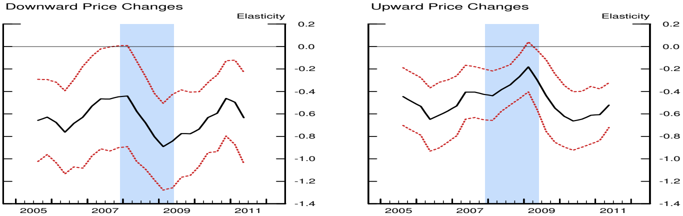
$$\Pr(\Delta p_{i,j,t+1}) = \begin{cases} + & \\ 0 & \text{(base)} \\ - & \end{cases} = \Lambda(\mathbf{X}_{j,t}; \boldsymbol{\beta}_t)$$

  - $\mathbf{X}_{j,t}$ = SGAX-to-sales ratio, liquidity ratio, other controls.
  - Includes time-varying fixed industry (3-digit NAICS) effects.
  - Estimated using four-quarter rolling window.

ELASTICITIES OF PRICE CHANGES



(a) With Respect to Liquidity Ratio



(b) With Respect to SGAX-to-Sales Ratio

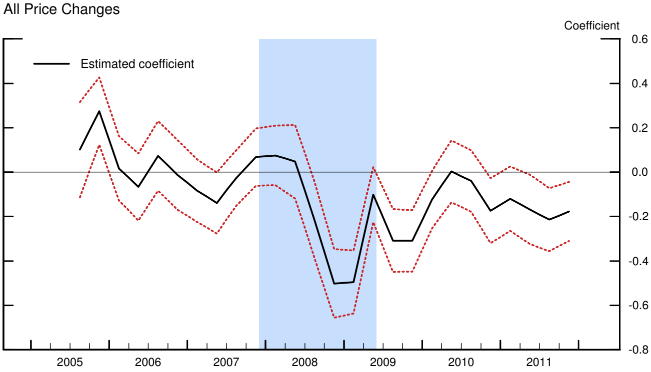
Price Adjustment and Firm Characteristics

- Price change regression:

$$\Delta p_{i,j,t+1} = \alpha_j + \beta X_{j,t} + \epsilon_{i,j,t}$$

  - $\mathbf{X}_{j,t}$ = SGAX-to-sales ratio, liquidity ratio, other controls.
  - Includes firm-level fixed effects: controls for many aspects of firm heterogeneity such as productivity.
  - Estimated using four-quarter rolling window.

PRICE CHANGE COEFFICIENTS



NOTE: Estimated Coefficients on Operating Income Ratio.

Preferences

- Household preferences display "Deep Habits."
  (Ravn, Schmitt-Grohe & Uribe [2006])
- Maximization problem:

$$\max \ \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U(x^j_{t+s} - \delta_{t+s}, h^j_{t+s}); \quad j \in [0,1]$$

  - Aggregator: $x^j_t \equiv \left[\int_0^1 \left(\frac{c^j_{it}}{s^{\theta}_{i,t-1}} \right)^{1-\frac{1}{\eta}} di \right]^{\frac{1}{1-\frac{1}{\eta}}}; \quad i \in [0,1]$
  - Law of motion: $s_{it} = \rho s_{i,t-1} + (1-\rho)c_{it}; \quad 0 < \rho < 1$
    - **Example**: Video games—the more you play, the more addicted you become!
  - δ_{t+s} = demand shock

Technology

- Production function (labor input, fixed operating costs):

$$y_{it} = \left[\frac{A_t}{a_{it}} h_{it}\right]^{\alpha} - \phi_i; \quad 0 < \alpha \leq 1$$

  - A_t = persistent aggregate technology shock
  - a_{it} = i.i.d. idiosyncratic technology shock with $\log a_{it} \sim N(-0.5\sigma^2, \sigma^2)$
- Heterogeneous fixed operating costs:
  - $\phi_i \in \mathbf{\Phi} = \{\phi_1, \ldots, \phi_N\}$, with $0 \leq \phi_1 < \phi_2 < \cdots < \phi_N$.
  - Firm measure: $\omega_1, \ldots, \omega_N$, with $\sum_{k=1}^{N} \omega_k = 1$.
- Benchmark model: $\phi_i = \phi$ (homogeneous firms)

Frictions

- Nominal rigidities:
  (Rotemberg [1982])

$$\frac{\gamma}{2}\left(\frac{P_{it}}{P_{i,t-1}}-\bar{\pi}\right)^2 c_t = \frac{\gamma}{2}\left(\pi_t\frac{p_{it}}{p_{i,t-1}}-\bar{\pi}\right)^2 c_t; \quad p_{it} \equiv \frac{P_{it}}{P_t}$$

- Financial frictions ⇒ costly equity financing
  (Myers & Majluf [1984]; Gomes [2001]; Stein [2003])
  - Dilution cost ($0 < \varphi < 1$): 1\$ of issuance brings in $(1-\varphi)$\$

$$\bar{\varphi}(d_{it}) \equiv -\left[d_{it} - \varphi \min\{0, d_{it}\}\right] = \begin{cases} -d_{it} & \text{if } d_{it} \geq 0 \\ -(1-\varphi)d_{it} & \text{if } d_{it} < 0 \end{cases}$$

Timing

- Within-period sequence of events:
  1. Aggregate information arrives in the morning
  2. Firms post prices based on aggregate information
  3. Take orders, plan production based on expected marginal cost
  4. Idiosyncratic shock realized after orders have been taken
  5. Firms meet demand based on originally posted prices and orders
- Facilitates aggregation and smooth solution.
  (Kiley & Sim [2012])

Symmetric Equilibrium

- Define an expectation operator:

$$\mathbb{E}_t^a[f(a_t;\mathbf{s}_t)] \equiv \int_0^\infty f(a_t;\mathbf{s}_t)dF(a)$$

  - Information set includes only the aggregate information $\mathbf{s}_t$.
- Symmetric equilibrium:
  - Firms with the same $\phi_k \in \mathbf{\Phi}$ choose identical relative price (p_{kt}) and production scale (c_{kt}).
  - Equilibrium dispersion in relative prices, inflation rates, etc.
  - Symmetric equilibrium does not apply to h_{it}, d_{it} (and other variables).

Firm Problem

- Maximize the expected present value of dividends:

$$\begin{aligned}\mathcal{L} \quad = \quad & \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \Bigg\{ d_{it} + \kappa_{it} \left[\left(\frac{A_t}{a_{it}} h_{it} \right)^{\alpha} - \phi_k - c_{it} \right] \\ & + \xi_{it} \left[p_{it} c_{it} - w_t h_{it} - \frac{\gamma}{2} \left(\pi_t \frac{p_{it}}{p_{i,t-1}} - \bar{\pi} \right)^2 c_t - \bar{\varphi}(d_{it}) \right] \\ & + \nu_{it} \left[\left(\frac{p_{it}}{\tilde{p}_t} \right)^{-\eta} s_{i,t-1}^{\theta(1-\eta)} x_t - c_{it} \right] + \lambda_{it} [\rho s_{i,t-1} + (1-\rho) c_{it} - s_{it}] \Bigg\}\end{aligned}$$

  - Externality-adjusted composite price index:
    $$\tilde{p}_t \equiv \left[\int_0^1 (p_{it} s_{i,t-1}^{\theta})^{1-\eta} di \right]^{1/(1-\eta)}$$
  - p_{it}, c_{it}, s_{it} chosen before the realization of idiosyncratic shock a_{it}.
  - d_{it}, h_{it} chosen after the realization of idiosyncratic shock a_{it}.

Shadow Value of Internal Funds

- FOC on dividends:

$$\xi(a_t;\phi_k) = \begin{cases} 1 & \text{if } a_t \leq a_t^E(\phi_k) \\ 1/(1-\varphi) & \text{if } a_t > a_t^E(\phi_k) \end{cases}$$

- External financing trigger:

$$a_t^E(\phi_k) = \frac{A_t}{w_t}\left[\frac{c_{kt}}{(c_{kt}+\phi_k)^{\frac{1}{\alpha}}}\right]\left[p_{kt} - \frac{\gamma}{2}\left(\pi_t\frac{p_{kt}}{p_{k,t-1}} - \bar{\pi}\right)^2\frac{c_t}{c_{kt}}\right]$$

- Expected shadow value of internal funds:

$$\begin{aligned} \mathbb{E}_t^a[\xi_{it} \mid \phi_k] &= 1 + \frac{\varphi}{1-\varphi}[1 - \Phi(z_t^E(\phi_k))] \geq 1 \\ z_t^E(\phi_k) &\equiv \frac{1}{\sigma}[\log a_t^E(\phi_k) + 0.5\sigma^2] \end{aligned}$$

Markups

- Aggregate markup:

$$\mu(A_t, c_t, w_t; \phi_k) = \alpha(A_t/w_t)(c_t + \phi_k)^{\frac{\alpha-1}{\alpha}}$$

- Financially-adjusted markup:

$$\begin{aligned}\tilde{\mu}(A_t, c_t, w_t; \phi_k) &\equiv \frac{\mathbb{E}_t^a[\xi_{it}|\phi_k]}{\mathbb{E}_t^a[\xi_{it}a_{it}|\phi_k]}\mu(A_t, c_t, w_t; \phi_k) \\ &\leq \mu(A_t, c_t, w_t; \phi_k) \\ \text{where} & \\ \mathbb{E}_t^a[\xi_{it}a_{it}|\phi_k] &= 1 + \frac{\varphi}{1-\varphi}[1 - \Phi(z_t^E(\phi_k) - \sigma)] \\ \mathbb{E}_t^a[\xi_{it}a_{it}] &\geq \mathbb{E}_t^a[\xi_{it}] \geq 1\end{aligned}$$

- Financial frictions increase marginal costs ⇒ lower markups.

Price-Setting Without Nominal Rigidities

- No customer markets:

$$p_{kt} = \eta \left[1 - \frac{1}{\tilde{\mu}_t(\phi_k)}\right]$$

- With customer markets:

$$\begin{aligned} p_{kt} &= \eta \left[1 - \frac{1}{\tilde{\mu}_t(\phi_k)}\right] \\ &+ \psi \mathbb{E}_t \left[\sum_{s=t}^{\infty} \tilde{\beta}_{t,s} \frac{\mathbb{E}^a_{s+1}[\xi_{i,s+1}|\phi_k]}{\mathbb{E}^a_t[\xi_{it}|\phi_k]} \left[1 - \frac{1}{\tilde{\mu}_{s+1}(\phi_k)}\right]\right] \end{aligned}$$

Inflation Dynamics

- Phillips curve with financial distortions:

$$p_{kt} = \gamma \pi_{kt} \pi_t \left(\pi_{kt} \pi_t - 1 \right) + \eta \left[1 - \frac{1}{\tilde{\mu}_t(\phi_k)} \right]$$
$$- \gamma \mathbb{E}_t \left[m_{t,t+1} \frac{\mathbb{E}^a_{t+1}[\xi_{i,t+1} | \phi_k]}{\mathbb{E}^a_t[\xi_{it} | \phi_k]} \pi_{k,t+1} \pi_{t+1} \left(\pi_{k,t+1} \pi_{t+1} - 1 \right) \frac{c_{t+1}}{c_{kt}} \right]$$
$$+ \psi \mathbb{E}_t \left[\sum_{s=t}^{\infty} \tilde{\beta}_{t,s} \frac{\mathbb{E}^a_{s+1}[\xi_{i,s+1} | \phi_k]}{\mathbb{E}^a_t[\xi_{it} | \phi_k]} \left[1 - \frac{1}{\tilde{\mu}_{s+1}(\phi_k)} \right] \right]$$

Discussion

- Valuation wedge:

$$\tilde{m}_{t,t+1} = m_{t,t+1} \frac{\mathbb{E}^a_{t+1}[\xi_{it+1}|\phi_k]}{\mathbb{E}^a_t[\xi_{it}|\phi_k]}$$

- Required return on equity deviates from the SDF of the owners.
- Dynamic liquidity condition:
  - Liquidity constrained firms ($\mathbb{E}^a_t[\xi_{it}|\phi_k] > \mathbb{E}^a_{t+1}[\xi_{it+1}|\phi_k]$) discount benefits of investment—the present value of future market shares—more heavily.
  - Application of LAPM to firm pricing-setting behavior. (Holmström and Tirole [2001])
  - Echoes the investment-cashflow sensitivity literature. (Fazzari et al. [1988]; Chirinko [1993]; Gilchrist & Himmelberg [1995])

Aggregation

- Symmetric equilibrium: $P_{it}^{1-\eta} = \sum_{k=1}^{N} \mathbf{1}(\phi_i = \phi_k) \times P_{kt}^{1-\eta}$
- Aggregate inflation:

$$
\begin{aligned}
\pi_t &= \frac{1}{P_{t-1}} \left(\int_0^1 P_{it}^{1-\eta} di \right)^{\frac{1}{1-\eta}} \\
&= \left[\sum_{k=1}^{N} \omega_k \left(\frac{P_{kt}}{P_{k,t-1}} \right)^{1-\eta} \left(\frac{P_{k,t-1}}{P_{t-1}} \right)^{1-\eta} \right]^{\frac{1}{1-\eta}}
\end{aligned}
$$

- Aggregate consumption:

$$
c_t = \left[\sum_{k=1}^{N} \omega_k [\exp \left[0.5\alpha(1+\alpha)\sigma^2 \right] h_{kt}^{\alpha} - \phi_k]^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}}
$$

Closing the Model

- Households:

$$
\begin{aligned}
m_{t,t+1} &= \beta \left[\frac{U_x(x_{t+1} - \delta_{t+1}, h_{t+1})}{U_x(x_t - \delta_t, h_t)} \right] \left[\frac{s_{t-1}^{\theta}}{s_t^{\theta}} \right] \\
\frac{w_t}{\tilde{p}_t} &= -\frac{U_h(x_t - \delta_t, h_t)}{U_x(x_t - \delta_t, h_t)} \\
c_t &= y_t - \sum_{k=1}^{N} \omega_k \frac{\gamma}{2} (\pi_t \pi_{kt} - 1)^2 c_t
\end{aligned}
$$

- Monetary policy:

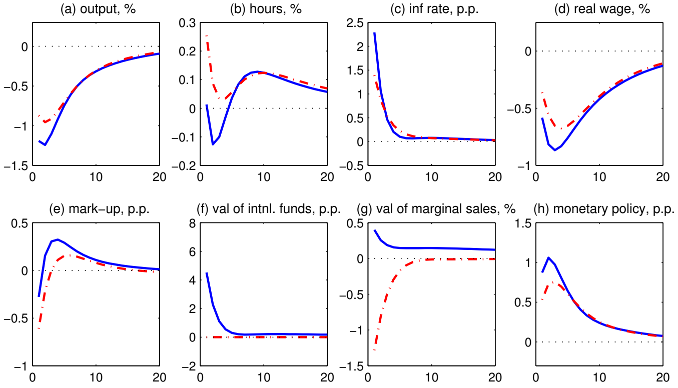
$$
r_t = \max \left\{ 0, (1 + r_{t-1})^{\rho_r} \left[(1 + \bar{r}) \left(\frac{\pi_t}{\pi^*} \right)^{\rho_\pi} \right]^{1-\rho_r} - 1 \right\}
$$

Calibration

Benchmark model: homogeneous firms

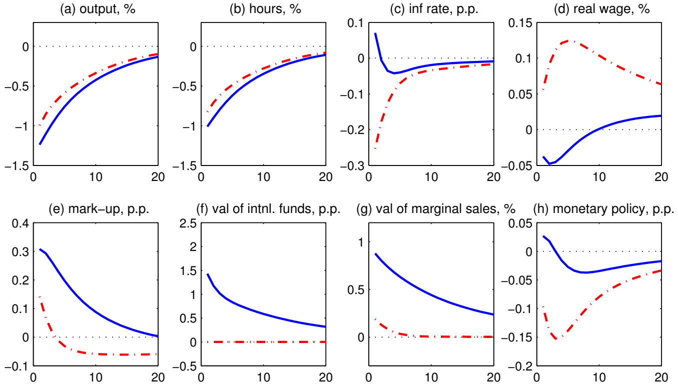
Parameter		**Value**
Preferences and Technology		
Relative risk aversion: γ_x		1.00
Deep habit: θ		-0.95
Persistence of deep habit: ρ		0.95
Elasticity of labor supply: $1/\gamma_h$		5.00
Elasticity of substitution: η		2.00
Fixed operating costs: ϕ		0.21
Idiosyncratic volatility (a.r.): σ		0.20
Financial Frictions		
Equity dilution costs: φ	0.30	0.50
Persistence of financial shock: ρ_φ		0.90

Crisis Experiment: Technology Shock



NOTE: Blue = model w/ financial frictions; Red = model w/o financial frictions.

Crisis Experiment: Demand Shock



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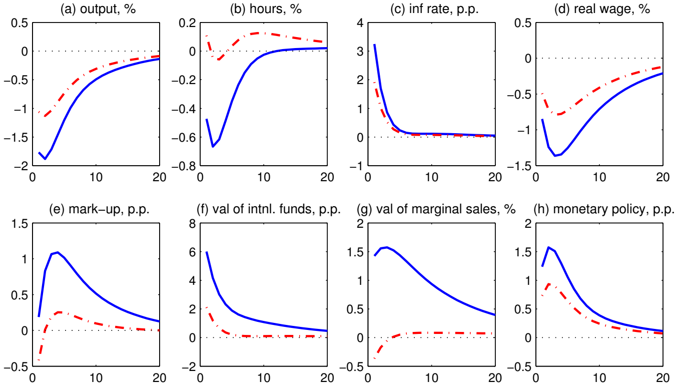
Technology and Financial Shocks



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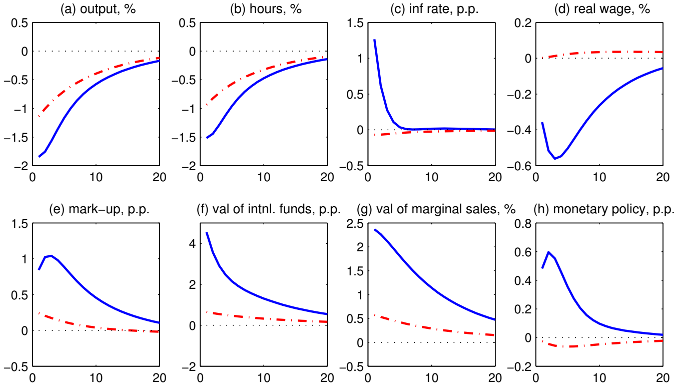
Demand and Financial Shock



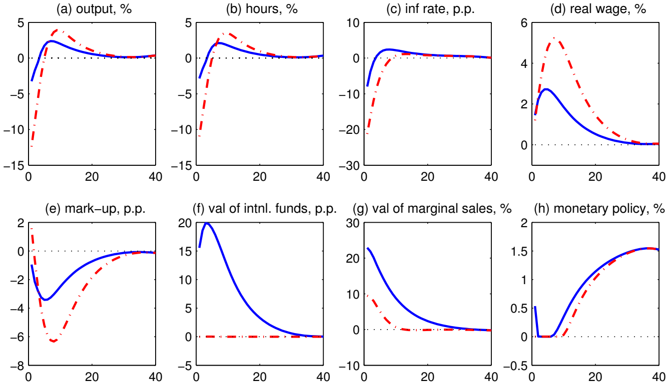
NOTE: Blue = model w/ financial frictions; Red = model w/o financial frictions.

Implications for Monetary Policy

“Divine coincidence” breaks down:

- Standard models:
  - no tradeoff between inflation and output stabilization for demand shocks
  - tradeoff between inflation and output stabilization following cost-push shocks
- Model with financial frictions and customer markets:
  - tradeoff also following demand shocks!

Discounting Rate Shock: the ZLB



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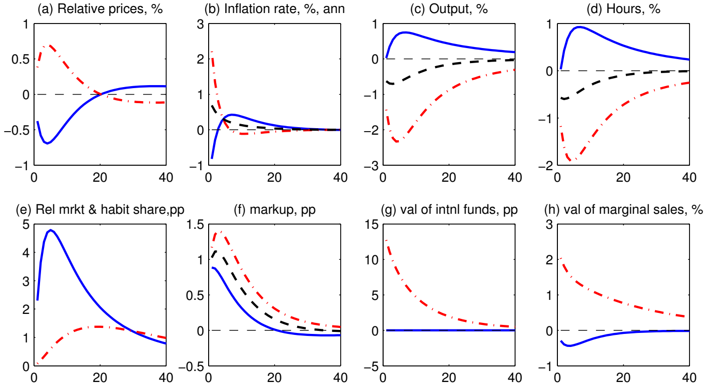
Financial Shock

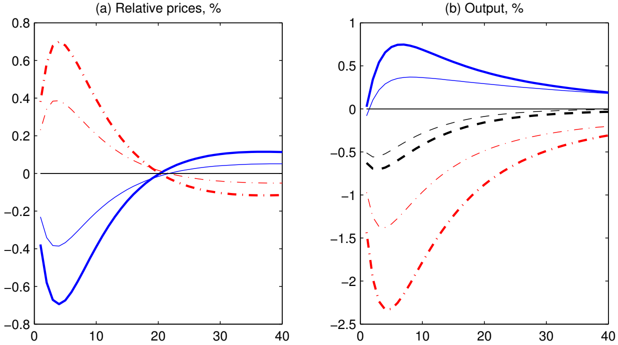
Heterogeneous fixed operating costs



NOTE: Blue = financially strong firms; Red = financially weak firms; Black = aggregate.

Paradox of Financial Strength

Heterogeneous fixed operating costs



NOTE: Blue = financially strong firms; Red = financially weak firms; Black = aggregate.

Conclusion

Mr. Marchionne and other auto executives accuse Volkswagen of exploiting the crisis to gain market share by offering aggressive discounts. "It's a bloodbath of pricing and it's a bloodbath on margins," he said.

The New York Times
July 25, 2012